Design of Miniaturized & Multiband Spiral Loaded Dipole Antenna for Wireless Communication

Goutam Kumar Das, Tarakeswar Shaw, Debasis Mitra*, and Monojit Mitra
Department of Electronics and Telecommunication Engineering,
Indian Institute of Engineering Science and Technology, Shibpur, Howrah-711103, India
**Corresponding author e-mail: debasisiit@gmail.com*

***Abstract*— In this paper, a miniaturized and multiband antenna without compromising their efficiency and bandwidth is designed. The proposed technique combines a metallic spiral with a dipole antenna. Similarly using two metallic spirals in two dipole arms effective antenna size are reduced further and also have a better return loss. The reference dipole antenna structure resonates at 4.4 GHz. By using two metallic spirals, we have achieved 24.15% reduction in resonance frequency as well as double band. The resonant frequencies are determined by controlling the number of turns of the spirals. The bandwidth is also enhanced by changing the gap between the top and bottom spirals. By the presence of these spirals, it is seen that the radiation pattern of the proposed design are unaffected.**

Index Terms – dipole, spiral loop, miniaturized, multiband, electrically small antennas.

I. INTRODUCTION

During past decade, the demand for wireless technology has increased significantly. In wireless and particularly low frequency application, miniaturization of antenna is becoming increasingly important. For the lower frequency operation, miniaturization techniques must be employed to keep antenna size practical. The multiband functionality is another required demand for wireless communication applications. Also, the radiation pattern, reasonable gain, and impedance bandwidth of the antenna should be in an acceptable limit. However, it was found that for designing of small antennas degrades the antenna bandwidth and efficiency [1].

One of the well-known technique to reduce the antenna size is by folding the antenna geometry. In [2], the technique has been used for the reduction of resonance frequency of antenna in a spherical helix, or with helical or meander-line structures. Using this technique, an electrically long antenna structure is folded to achieve a reduced size. Top-loading [3] is another way of miniaturization of antenna.

Recently in [4], a novel miniaturization of dipole and monopole antennas using loop loading technique is discussed. Another miniaturization technique for slot antennas using slit/strip loading was reported in [5], whereas a wire-loaded miniaturized slot antenna structure was addressed [6].

In addition to miniaturization, multiband operation for antenna is also essential for wireless application. For multiband operation for dipole antenna by using folding and asymmetric technique was reported in ref. [7] and [8] respectively. Recently, a dual band wire monopole antenna has been designed by applying frequency selective surface (FSS)-based corner reflector [9].

In this paper we are using spiral structure to design a miniaturized multiband dipole antenna. For the proposed antenna, about 24.15% reduction in resonance frequency has been achieved. Here, by using one metallic spiral in the reference dipole structure the resonance frequencies are 2.17 GHz at -20.18 dB and 3.70 GHz at -16.83 dB. In case of two spirals, the resonant frequencies are 1.97 GHz at -18.41 dB and 3.36 GHz at -26.74 dB. Therefore good level of matching characteristics is observed for both the frequency band. The radiation performance of the proposed design is completely unchanged compared with the unloaded dipole in this case.

II. DESIGN

The design procedure starts by choosing the reference dipole antenna of length 30 mm which resonate at a frequency of 4.43 GHz. The conductor used for the antenna design is copper wire having finite conductivity of 5.8×10^7 Siemens/m. To reduce the resonance frequency we use a spiral of two turns with suitable thickness and width. Spiral loaded dipole gives dual band [10] frequencies similar to U-shaped slots of PIFA antenna [11]. Similarly for getting tri-band [12] we can use three turns spiral. Spiral loading also shifts resonant frequency that gives miniaturization.

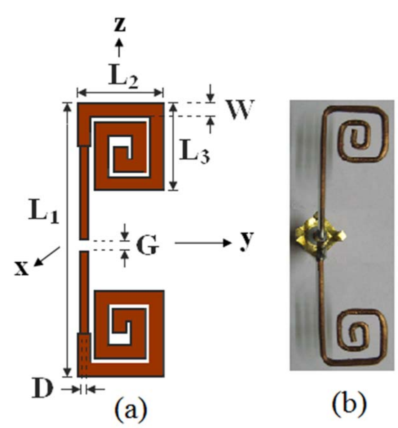

Figure 1. Spiral loaded dipole antenna (a) Geometry (b) Fabricated Photograph

The reference dipole antenna dimensions are, arm length=30mm, diameter of arm=01mm, gap between two arms=0.50mm. Dimensions of our proposed spiral loaded dipole antenna of Fig. 1 are as follows. L1=30mm,

L2=8mm, L3=8mm, the gap between two arms of spiral loaded antenna, G=0.50mm, the diameter of spiral arm, D=01mm. The width of spiral W=1.5mm and the thickness of spiral is 2mm.

III. RESULTS

In this work, Ansoft high-frequency structure simulator software is used for antenna simulation and the vector network analyzer (N5230A) is used for measurement of return loss (S_{11}) of the antenna. Simulated and measured return losses characteristics are shown in Fig. 2.

Return loss: It is observed from Fig. 2 that the simulated resonant frequencies are 1.97 GHz and 3.36 GHz respectively whereas measured are 1.94 GHz and 3.34 GHz are shown in Table1. A good matching characteristic with the coaxial feed is observed for the miniaturized dipole antenna. In addition, the measured 10-dB bandwidth of the spiral-loaded dipole antenna are 6.09% and 10.08%, where measured bandwidth is 5.82% for the reference dipole antenna.

Impedance: The input impedance characteristics of the proposed design is shown in Fig. 3. At the resonant frequency (1.97GHz), the imaginary part is equal to zero whereas the real part is around 46 ohm. At the upper resonant frequency (3.36GHz), the imaginary part is zero as the real part is about 55 ohm.

Radiation pattern: The radiation patterns are unchanged for both the reference and spiral dipole. Fig. 4 and Fig. 5 show the comparison between the simulated and measured E-plane and H-plane radiation pattern. For both the frequencies, it is also seen that the cross-polarization levels in the H-plane are low. At the resonating frequencies, the measured gain of the loaded antenna is 1.43 dBi and 1.62dBi compared with 2.98 dBi measured for the reference dipole.

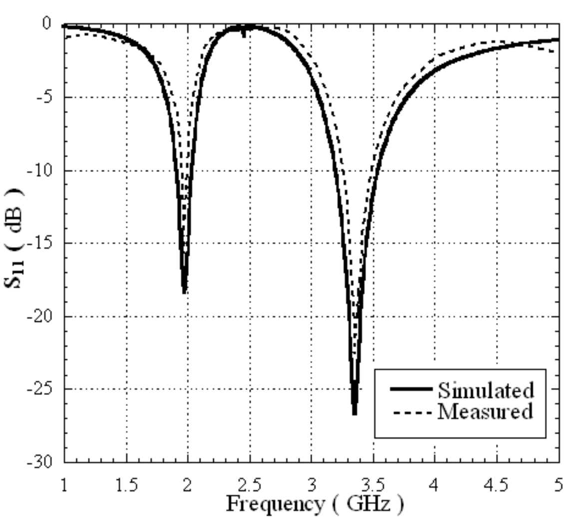

Figure 2. Return Loss characteristics of spiral loaded dipole antenna.

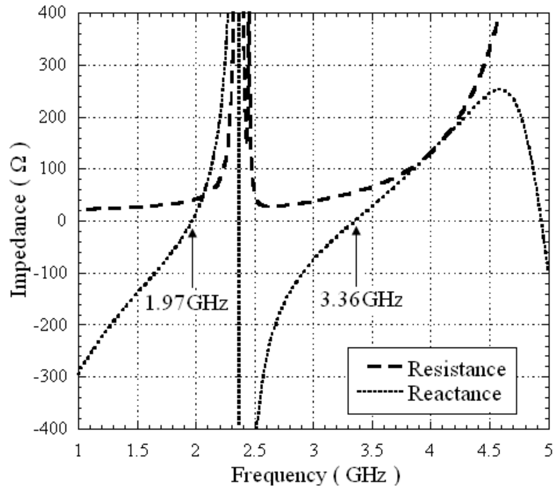

Figure 3. Input impedance of spiral loaded dipole antenna.

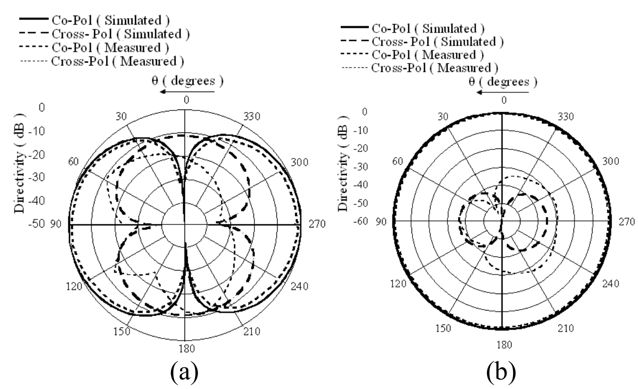

Figure 4. Radiation pattern at lower resonating frequency (a) E-plane and (b) H-plane.

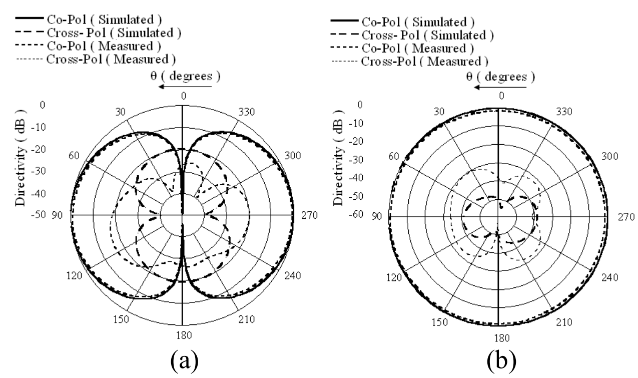

Figure 5. Radiation pattern, at upper resonating frequency (a) E-plane (b) H-plane.

Fig. 6 shows the simulated E field distributions for the proposed antenna at resonance. The E field inside the dipole is increased on the dipole rings. Thus, the resonant frequency of the proposed antenna is shifted to the left side, subsequently, miniaturization is obtained.

TABLE 1: Measured spiral loaded dipole antenna parameters

Parameters	Ref. Antenna	Spiral Antenna	
	f=4.4 GHz	f=1.94 GHz	f=3.34 GHz
Gain (dB)	2.98	1.43	1.62
Efficiency	99.46%	92.27%	97.37%
10 dB Band width	5.82%	6.09%	10.08%

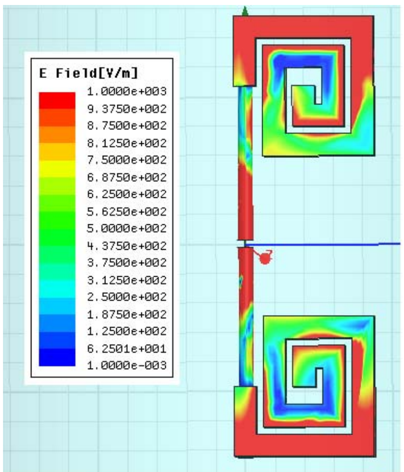

Figure 6. Field distribution of spiral dipole antenna.

IV. CONCLUSION

A miniaturized, multiband dipole antenna using spiral loading is presented in this paper. Even with a high level of miniaturization, the antenna structure is very easy to feed. The antenna also possesses a better bandwidth than the unperturbed dipole. As expected, there is a trade off between bandwidth and size reduction. In lower resonant frequency the 10 dB band width is less with respect to higher resonant frequency as shown in Table 1. By changing the number of turns in spiral, triple band has also been observed. The radiation pattern of the proposed dipole antenna is unchanged by the loading of the spiral structure. Therefore, the proposed dipole antenna is expected to find applications in various wireless communications.

ACKNOWLEDGMENTS

T. Shaw acknowledges the Visvesvaraya PhD scheme for Electronics & IT research fellowship award and D. Mitra acknowledges the Visvesvaraya Young Faculty research fellowship award, under MeitY, Govt. of India.

REFERENCES

[1] J.S. McLean, "A re-examination of the fundamental limits on the radiation Q of electrically small antennas," *IEEE Trans. Antennas Propagat.*, vol. 44, pp. 672–676, May 1996.

[2] S.R. Best, "The radiation properties of electrically small folded spherical helix antennas," *IEEE Trans. Antennas Propagat.*, vol. 52, pp. 953–960, Apr. 2004.

[3] N. Behdad and K. Sarabandi, "Bandwidth enhancement and further size reduction of a class of miniaturized slot antennas," *IEEE Trans. Antennas Propagat.*, vol. 52, pp. 1928–1935, Aug. 2004.

[4] B, Ghosh, M. Haque, D. Mitra, and S, Ghosh, "A Loop Loading Technique for the Miniaturization of Non-planar and Planar Antennas", *IEEE Trans. Antennas Propagat.*, Vol 58, Issue 6 , June 2010.

[5] B. Ghosh, S. K. M. Haque, and D. Mitra, "Miniaturization of slot antenna using slit and strip loading," *IEEE Trans. Antennas Propag.*, vol. 59,no. 10, pp. 3922–3927, Oct. 2011.

[6] B. Ghosh, S. K. M. Haque, and N. R. Yenduri, "Miniaturization of slot antennas using wire loading," *IEEE Antennas Wireless Propag. Lett.*,vol. 12, pp. 488–491, Apr. 2013.

[7] D. Zhou, R. A. Abd-Alhameed, C. H. See, and P. S. Excell, "Design of Multiband Balanced Folded Dipole Antenna Based on a Dual-arm Structure for Mobile Handsets, " *PIERS online*, Vol. 4, NO. 8, 2008.

[8] C.-M. Peng, I.-F. Chen, and C. Hao Liu, "Multiband Printed Asymmetric Dipole Antenna for LTE/WLAN Applications," Hindawi, *International Journal of Antennas and Propagation*, Vol. 2013, Article ID 704847.

[9] A. Chatterjee, and S. K. Parui, "Performance Enhancement of a Dual-Band Monopole Antenna by Using a Frequency-Selective Surface-Based Corner Reflector," *IEEE Trans. Antennas Propagat.,* Vol. 64, pp. 2165-2171, 2016.

[10] M. J. Kim, C. S. Cho, and J. Kim, "A Dual Band Printed Dipole Antenna With Spiral Structure for WLAN Application," *IEEE Microwave and Wireless Components Letters,* Vol. 15, No. 12, Dec. 2005.

[11] D. M. Nashaat, H. A. Elsadek, and H. Ghali, "Single Feed Compact Quad-Band PIFA Antenna for Wireless Communication Applications," *IEEE Trans. Antennas Propagat.* Vol. 53, No. 8, Aug. 2005.

[12] S.R. Best, "The performance properties of electrically small resonant multiple-arm folded wire antennas," *IEEE Antennas Propag. Mag.*, vol. 47, no. 4, pp. 13-27, Aug. 2005.